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(54) A spark plug for an internal combustion engine

(57) In a spark plug (1) for an internal combustion engine, an insulator (2) has a concentric axial bore (2a) in which a center electrode (3) is placed with a front end (3a) of the center electrode extending beyond a front end portion (2b) of the insulator. A metallic shell (4) is placed to support the insulator (2). An outer electrode (5) is connected to a front end (4a) of the metallic shell (4) to form a spark gap (G) with the front end portion (3a) of the center electrode (3). At least an outer surface of the outer electrode (5) is formed by a smoothly curved profile so as to smoothly run air-fuel mixture along the outer electrode (5).

Fig. 4a

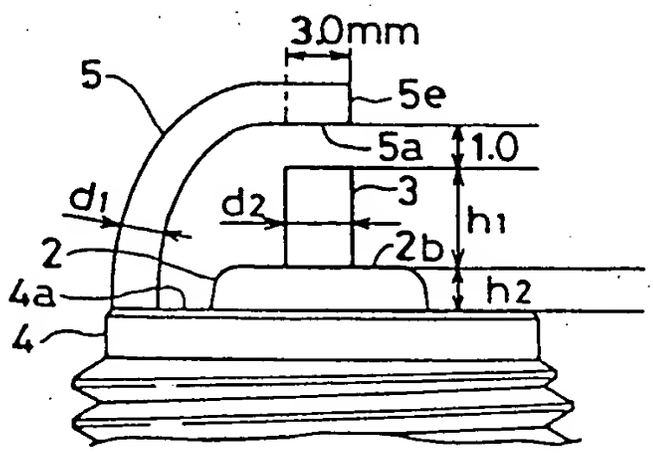

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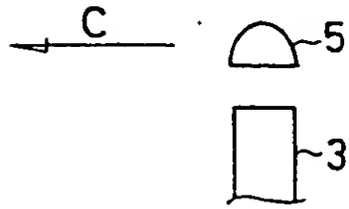
Fig. 4b



Description

This invention relates to a spark plug for use in an automotive internal combustion engine.

With the recent requirement of an enhanced fuel efficiency, it has been demanded to run an automobile engine with rarefied fuel gas. In realizing the lean burn engine, it is quitessential to significantly improve an ignitability of the spark plug to burn rarefied fuel gas so as to run the engine with the lean burn operation. In order to satisfy the requirement, a spark plug has been conceived in which a center electrode is substantially extended for an ignition position near to a center of a combustion chamber of the internal combustion engine.

In a prior spark plug, however, an outer electrode has been used whose cross sectional shape is rectangular. Due to the angles of the rectangular section of the outer electrode, a flue extinguishing effect (a cooling effect) appears to impede a flame core to grow, and at the same time, a swirl of an air-mixture gas is disturbed so as to deteriorate the ignitability against the air-mixture gas. This is all the more particularly when the electrode is extended longer into the combustion chamber of the internal combustion engine. While at the same time, the ignitability is influenced depending on which side the outer electrode is oriented when the spark plug is mounted on a cylinder head of the internal combustion engine.

Therefore, it is one of the objects of the invention to provide a spark plug for an internal combustion engine which is capable of uniformly improving an ignitability regardless of which side an outer electrode is oriented.

According to the present invention, there is provided a spark plug comprising

an insulator having an axial bore;
a center electrode placed within the axial bore of the insulator, a front end portion of the center electrode extended beyond a front end of the insulator;
a metallic shell supporting the insulator;
at least one outer electrode connected to a front end of the metallic shell to form a spar gap with the front end portion of the center electrode; and

wherein at least a portion of the outer surface of said at least one outer electrode is formed to have a smoothly curved profile.

The spark plug may have an outer electrode whose firing surface is formed into a flat-shaped configuration to provide the spark gap with a front end surface of the center electrode.

Alternatively or in addition, the spark plug may have at least one outer electrode forming a spark gap with an elevational side of the center electrode.

In some forms of the present invention, a cross-section of the front firing side surface of the outer electrode is formed into a semi-circular or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more, while a cross-section of the other portion of the outer electrode except for the front firing side surface is formed into a circular, semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more.

In other forms of the present invention, the outer electrodes other than one forming the spark gap with the front end surface of the center electrode, form a spark gap with an elevational side of the center electrode, a cross section of the outer electrode being a semi-circular, elliptical or polygonal shape having corners rounded to have a radius of 0.5 mm or more.

A cross-section of the outer electrode may be formed into a semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more. At least the outer surface of the outer electrode may be formed by the smoothly curved profile against the center electrode, and be located at a portion ahead of a base portion in which the outer electrode is connected to the metallic shell. A cross-section of the portion ahead of a base portion in which the outer electrode is connected to the metallic shell, may be formed into a circular, semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more.

The outer electrode which forms the spark gap with the elevational side of the center electrode may have a front firing end formed into a flat-shaped configuration.

The outer electrode which forms the spark gap with the elevational side of the center electrode may have a front firing end formed into a bight-shaped notch corresponding to the elevational side of the center electrode.

With the invention, at least the outer surface of the outer electrode is formed by a smoothly curved profile against the center electrode. This means it is possible to reduce the influence of the outer electrode against the streams of the air-fuel mixture. That is to say, the smoothly curved profile makes it possible to substantially decrease the disturbance against the air-fuel mixture streams so as to insure smooth streams of the air-fuel mixture admitted to an ignition portion without impeding an entry of the streams into the ignition portion, and thus enables to an improved ignitability and a decreased variation of the ignitability depending on which side the outer electrode is oriented.

With the smoothly curved profile located at a portion ahead of a base end in which the outer electrode is connected to the metallic shell, it is also possible to reduce the influence of the outer electrode against the streams of the air-fuel mixture. Namely, the smoothly curved profile makes it possible to substantially decrease the disturbance against the air-fuel mixture streams so as to insure smooth streams of the air-fuel mixture admitted to an ignition portion without impeding an entry of the streams into the ignition portion, and thus enables to an improved ignitability and a decreased variation of the ignitability depending on which side the outer electrode is oriented.

With the front firing side surface of the outer electrode formed into a flat-shaped configuration so as to provide the spark gap with the front end portion of the center electrode, it is possible to effectively resist against spark erosion so as to contribute to an extended service life. It is noted "the smoothly curved profile" signifies that the outer surface is not angular without having any edged corner through all these instances.

These and other objects, aspect and embodiments of the invention will be described in more detail, by way of example only, with reference to the following drawing figures, of which:-

Fig. 1 is a half longitudinal cross sectional view of a firing portion of a spark plug according to a first embodiment of the invention;
Fig. 2 is a latitudinal cross sectional view of an outer electrode taken along the lines A-A of Fig. 1;
Figs. 3a and 3b are latitudinal cross sectional views of an outer electrode taken along the lines B-B of Fig. 1;
Fig. 4a is an elevational view of the firing portion of the spark plug;
Fig. 4b is an elevational view of the firing portion of the spark plug looked from an arrow C of Fig. 4a;
Fig. 5a is an elevational view of the firing portion of the spark plug;
Fig. 5b is an elevational view of the firing portion of the spark plug looked from an arrow D of Fig. 5a;
Fig. 6 is a graph shown to compare an ignitability between the prior art and the present invention;
Fig. 7a, 7b and 7c are latitudinal cross sectional views of various outer electrodes according to a second embodiment of the invention;
Fig. 8 is a half longitudinal cross sectional view of a firing portion of a spark plug according to a third embodiment of the invention;
Fig. 9 is a half longitudinal cross sectional view of a firing portion of a spark plug according to a fourth embodiment of the invention;
Fig. 10a is a plan view of a firing portion of a spark plug according to a fifth embodiment of the invention;
Fig. 10b is a half longitudinal cross sectional view of a firing portion of a spark plug according to the fifth embodiment of the invention;
Fig. 11a is a plan view of a firing portion of a spark plug according to a sixth embodiment of the invention;
Fig. 11b is a half longitudinal cross sectional view of a firing portion of a spark plug according to the sixth embodiment of the invention;
Fig. 12 is a half longitudinal cross sectional view of a firing portion of a spark plug according to a seventh embodiment of the invention; and
Fig. 13 is a half longitudinal cross sectional view of a firing portion of a spark plug according to an eighth embodiment of the invention.

Referring to Figs. 1, 2, 3a, 3b, 4a and 4b which show an upper portion of a spark plug 1 according to a first embodiment of the invention, the spark plug 1 has a center electrode 3 and an outer electrode 5. The center electrode 3 is placed within an axial bore 2a of an insulator 2, and the ground electrode 5 is connected to a front end 4a of a metallic shell 4 which supportedly encloses the insulator 2. The center electrode 3 locates its front end surface 3a to form a spark gap G with the outer electrode 5.

The center electrode 3 is a composite structure in which a copper or copper based core is embedded in a nickel or nickel based clad, and the front end surface 3a of the center electrode 3 is extended beyond a front end 2b of the insulator 2 by a predetermined length.

The outer electrode is made of a nickel or nickel based alloy, and having one end turned toward the front end surface 3a of the center electrode 3, while having the other end welded to the front end 4a of a metallic shell 4. Except for a front firing side surface 5a of the outer electrode 5 which forms the spark gap G with the front end surface 3a of the center electrode 3, a cross sectional shape of the outer electrode 5 is circular as shown in Fig. 2. The front firing side surface 5a of the outer electrode 5 is formed into a flat-shaped configuration, and a cross section of the outer electrode 5 including the front firing side surface 5a has a semi-circular shape or rectangular (square) shape whose four corners (R) are rounded to have a radius of 0.5 mm or more as shown in Figs. 3a and 3b. In Figs. 3a and 3b, the semi-circular surface 5g and the rounded corners (R) of the outer electrode 5 serve as a smoothly curved profile to rectify streams of air-fuel mixture flowing along the outer electrode 5 upon taking the air-fuel mixture into a combustion chamber of the internal combustion engine.

The outer electrode 5 is manufactured as follows:

(i) A linear blank circular in cross section is welded to the front end 4a of the metallic shell 4, and thereafter cut into a predetermined length.
(ii) Its front end portion which is to form the spark gap G with the center electrode 3 is pressed to form into the circular or rectangular (generally square) cross section by means of pressing procedure so as to provide the flat-shaped configuration (front firing side surface 5a) at one side which is to meet the front end surface 3a of the center electrode 3.
(iii) Then, a front portion of the outer electrode 5 is turned toward the center electrode 3 to face the front end surface 3a of the center electrode 3 so as to form the spark gap G whose width is substantially uniform from one side to another.

With the outer electrode 5 substantially rectangular or semi-circular in cross section, it is possible to reduce the influence of the outer electrode 5 against the streams of the air-fuel mixture. That is to say, the outer electrode 5 is formed into a smoothly curved profile

which makes it possible to substantially decrease a fluid resistance against the air-fuel mixture streams so as to insure smooth streams of the air-fuel mixture admitted to an ignition portion without impeding an entry of the streams into the ignition portion, and thus enables to an improved ignitability and a decreased variation of the ignitability depending on which side the outer electrode 5 is oriented.

An experimental test was carried out to compare the ignitability (lean burn limit air-to-fuel ratio) between the outer electrode 5 of the present invention (Figs. 4a and 4b) and an outer electrode 50 of a prior art spark plug (Figs. 5a and 5b). In this instance, the outer electrode 5 employed by the spark plug 1 measures 1.7 mm in diameter (d1). A lateral region extended by 3.0 mm from a front end surface 5e of the outer electrode 5 with the front firing side surface 5a included, is formed into a generally semi-circular shape in cross section.

Meanwhile, the prior outer electrode 50 is rectangular in cross section, and measures 2.8 mm (w: width) × 1.6 mm (t: thickness). In both the present outer electrode 5 and the prior outer electrode 50, the center electrodes 3, 30 measure 2.6 mm in diameter (d2), and extend by 8.5 mm (h1) beyond the front ends 2b, 20b of the insulators 2, 20 respectively. Front ends of the insulators 2, 20 extend by 1.5 mm (h2) beyond the front ends 4a, 40a of the metallic shells 4, 40 respectively.

Fig. 6 shows an experimental test result by comparing the ignitability (lean burn limit air-to-fuel ratio) between the outer electrode 5 of the present invention and the outer electrode 50 of the prior art spark plug. In the prior outer electrode 50 made by the rectangular blank, it is found that the ignitability reduces such a degree as to unacceptably vary depending on which side the outer electrode is oriented when mounting the spark plug on the cylinder head of the internal combustion engine. In the outer electrode 5 according to the present invention, it is found that the ignitability is improved, and its variation decreases depending on which side the outer electrode is oriented when mounting the spark plug on the cylinder head of the internal combustion engine.

Since the front firing side surface 5a of the outer electrode 5 is formed into the flat-shaped configuration to provide the spark gap G with the front end surface 3a of the center electrode 3, it is possible to lessen an amount of the spark erosion so as to extend the service life, as opposed to an instance in which an convex portion meets the front end surface 3a of the center electrode 3.

Figs. 7a, 7b and 7c show a second embodiment of the invention in which a cross section of the outer electrode 5 is a semi-circular, elliptical or rectangular shape whose four corners (R) are rounded to have a radius of 0.5 mm of more. It is preferable to form the cross section of the outer electrode 5 into a generally squarely shaped configuration when taking the fluid resistance and flame extinguishing effect into consideration. In these instances, it is observed that the cross section of the outer electrode 5 is a semi-circular or rectangular (including generally square) shape whose corners are rounded to have a radius of 0.5 mm of more when cutting at the front firing side surface 5a of the outer electrode 5 in the same manner as described in the first embodiment of the invention.

Fig. 8 shows a third embodiment of the invention in which the outer electrode 5 is a composite structure having a copper or copper-based core 5c embedded in a nickel or nickel-based clad 5b in order to facilitate a heat-drawing action so as to suppress an oxidation-based erosion of the outer electrode 5.

Fig. 9 shows a fourth embodiment of the invention in which a front end portion of the center electrode is thinned such as to be 1.0 ~ 1.5 mm in diameter (d), and a spark-erosion resistant noble tip 6 welded to the front end surface 3a of the center electrode 3 so as to form the spark gap G with the outer electrode 5. In this instance, the noble tip 6 is made of Pt, Ir, Pt-Ir based alloy or Pt-Ni based alloy. With the center electrode 3 thus thinned, it is possible to lessen the flame extinguishing effect so as to improve the ignitability, and at the same time, enhancing the durability of the center electrode 3 by welding to the noble metal tip 6 to the center electrode 3.

In addition to the noble tip 6 welded to the center electrode 3, an additional noble metal tip 6a can be welded to the front firing side surface 5a of the outer electrode 5 as shown at the upper position in Fig. 9. In this instance, the noble tip 6a is made of Pt, Ir, Pt-Ir based alloy or Pt-Ni based alloy.

With the noble metal tip 6a thus welded to the front firing side surface 5a of the outer electrode 5, it is possible to increase the durability of the outer electrode 5. In this occasion, it stands as a matter of course that in the first through fourth embodiments of the invention, the noble metal tip may be solely welded to the front end surface 3a of the center electrode 3 or the front firing side surface 5a of the outer electrode 5.

Figs. 10a and 10b show a fifth embodiment of the invention in which two outer electrodes 5, 5 are provided diametrically opposed with the center electrode 3 interposed therebetween. In this instance, each of the outer electrodes 5, 5 turned toward the center electrode 3 so that the front firing end 5e of the outer electrode 5 faces an elevational side 3s of the center electrode 3. The front firing end 5e of the outer electrode 5 is formed into a bight-shaped notch to be located in concentrical relationship with the center electrode 3. The front firing end 5e serves as a front firing end surface which cooperates with the elevational side 3s of the center electrode 3 so as form the spark gap G whose width dimension is substantially uniform in both lateral and vertical directions, thus preventing the spark erosion from occurring locally on a limited area so as to impart the spark-erosion resistancy with the center electrode 3.

Figs. 11a and 11b show a sixth embodiment of the invention in which two outer electrodes 5, 5 are provided

diametrically opposed with the center electrode 3 interposed therebetween in the same manner as described in the fourth embodiment of the invention. Each of the outer electrodes 5, 5 turned toward the center electrode 3 so that the front firing end 5e of the outer electrode 5 faces the elevational side of the center electrode 3. However, the front firing end 5e of the outer electrode 5 is formed into a flat-shaped configuration as shown in Fig. 11a. The front firing end 5e serves as a front firing end surface which cooperates with the elevational side 3s of the center electrode 3 so as form the spark gap G whose width dimension progressively increases from the center to right and left directions, thus making it possible to lessen the flame extinguishing effect which impedes the flame core to develop so as to enhance the ignitability. It is observed that in the fifth and sixth embodiments of the invention, the cross section of the outer electrode 5 may be a semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more.

Fig. 12 shows a seventh embodiment of the invention in which one of two outer electrodes 5i, 5j forms a spark gap Gi with the front end surface 3a of the center electrode 3, and the other outer electrode 5j is located at its front firing end 5e to form a spark gap Gj with the elevational side 3s in the same manner as described in the fifth and sixth embodiments of the invention. In this instance, the cross section of the front firing end 5e of the outer electrode 5j may have the bight-shaped notch or flat-shaped configuration in the same manner as described respectively in the fifth and sixth embodiments of the invention.

Fig. 13 shows an eighth embodiment of the invention in which a projected length (L) of the center electrode 3 is increased so as to form a so-called projected type spark plug. The projected length (L) signifies an axial dimension in which the front end surface 3a of the center electrode 3 extends from a wall portion 7 of a combustion chamber Ci toward a center of the combustion chamber Ci of the internal combustion engine. In this instance, the projected length (L) is predetermined to be 5 mm or more.

It is preferable to employ the outer electrode 5 to the projected type spark plug which is intended to burn the rarefied fuel gas. With the result of employing the outer electrode 5 to the projected type spark plug, it is possible to significantly improve the ignitability, while at the same time, lessening the variation of the ignitability depending on which side the outer electrode 5 is oriented when installing the spark plug on the cylinder head of the internal combustion engine. This is all the more effective particularly when running the internal combustion engine with the lean burning operation which is strongly influenced by the swirls caused from intaking the air-fuel mixture. By forming the outer electrode 5 into the composite structure having clad and core, it is possible to increase the heat-drawing action of the outer electrode 5 so as to significantly improve its durability leading to an extended service life.

In the outer electrode 5 as described in the first through eighth embodiments of the invention, the cross section of the outer electrode 5 may be a circular, semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more at a portion ahead of a base in which the outer electrode 5 is connected to the front end 4a of the metallic shell 4. In a ninth embodiment of the invention, the cross-section of the outer electrode 5 is formed into a rectangular shape at the base in which the outer electrode 5 is connected to the front end 4a of the metallic shell 4.

With the cross section of the outer electrode 5 as rectangular only at the base in which the outer electrode 5 is connected to the front end 4a of the metallic shell 4, it is possible to enlarge a welding area of the outer electrode 5 against the metallic shell 4 so as to strengthen a union therebetween, and the same time, ameliorating the heat-drawing action through the metallic shell 4 so as to increase the durability of the outer electrode 5. This is all the more effective particular when a thickness of the front end 4a of the metallic shell 4 is reduced by enlarging an annular space between an inner wall of the metallic shell 4 and a leg portion of the insulator 2 in order to resist against carbon fouling deposited on the insulator 2. This also holds true when applied to a thickness-reduced type spark plug since the thickness of the front end 4a of the metallic shell 4 tends to be reduced with the decrease of a diametrical dimension of a male thread portion provided on the metallic shell 4.

It is noted that the present invention may be applied to a multi-polarity type spark plug in which a plurality of outer electrodes are provided so that the number of the outer electrodes is three, four, five or more.

While the invention has been described with reference to the specific embodiments, it is understood that this description is not to be construed in a limiting sense in as much as various modifications and additions to the specific embodiments may be made by skilled artisans without departing from the scope of the invention.

Claims

1. A spark plug comprising

an insulator having an axial bore;
a center electrode placed within the axial bore of the insulator, a front end portion of the center electrode extended beyond a front end of the insulator;
a metallic shell supporting the insulator;
at least one outer electrode connected to a front end of the metallic shell to form a spark gap with the front end portion of the center electrode; and

wherein at least a portion of the outer surface

of said at least one outer electrode is formed to have a smoothly curved profile.

2. A spark plug according to claim 1, having an outer electrode whose firing surface is formed into a flat-shaped configuration to provide the spark gap with a front end surface of the center electrode.

3. A spark plug according to claim 1 or 2, having at least one outer electrode forming a spark gap with an elevational side of the center electrode.

4. A spark plug according to claim 3, wherein the or each outer electrode which forms a spark gap with the elevational side of the center electrode has a front firing end formed into a flat-shaped configuration.

5. A spark plug according to claim 3 or 4, wherein the or each outer electrode which forms a spark gap with the elevational side of the center electrode has a front firing end formed into a bight-shaped notch corresponding to the elevational side curvature of the center electrode.

6. A spark plug according to any one of the preceding claims, wherein the cross-section of at least one outer electrode is a semi-circular, elliptical or polygonal shape having corners rounded to have a radius of 0.5 mm or more.

7. A spark plug according to any one of the preceding claims, wherein the cross-section of the front portion of at least one outer electrode is formed into a semi-circular or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more, while the cross-section of the other portion of the at least one outer electrode except for the front portion is formed into a circular, semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more.

8. A spark plug according to any one of claims 1 to 5, wherein the outer surface of at least one outer electrode formed by a smoothly curved profile is located at a portion ahead of a base portion of said at least one outer electrode by which said outer electrode is connected to the metallic shell.

9. A spark plug according to claim 8, wherein the cross-section of the portion ahead of a base portion by which the outer electrode is connected to the metallic shell, is formed into a circular, semi-circular, elliptical or polygonal shape whose corners are rounded to have a radius of 0.5 mm or more.

10. A spark plug according to any one of the preceding claims, wherein the front end surface of the center electrode is adapted to extend into a combustion chamber by 5 mm or more.

11. A spark plug according to any one of the preceding claims, wherein the at least one outer electrode has a copper or copper-based core.

12. A spark plug according to any one of the preceding claims, wherein a noble metal tip or noble metal based tip is at least partly provided on a portion at which the at least one outer electrode forms the spark gap with the center electrode.

13. A spark plug according to any one of the preceding claims, wherein the center electrode has a noble metal tip or noble metal based tip at a front firing end which forms the spark gap with the at least one outer electrode.

Fig. 1

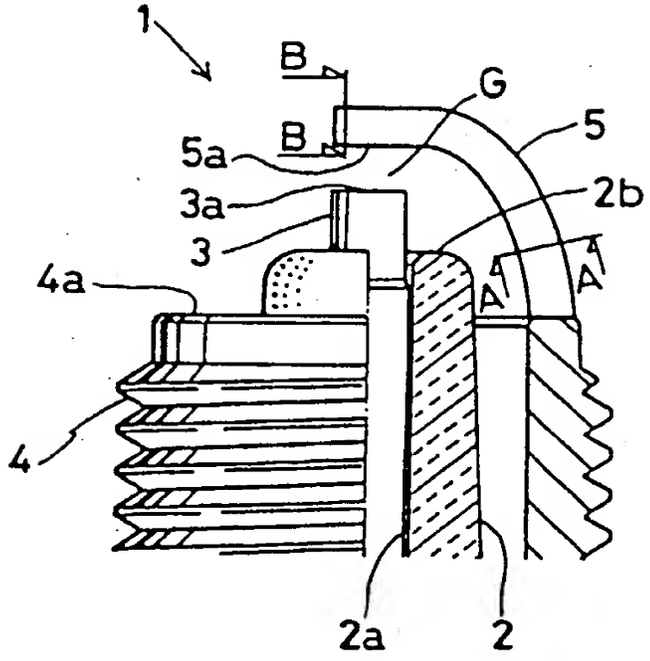


Fig. 2

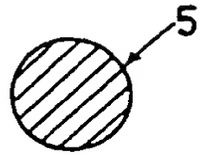


Fig. 3a

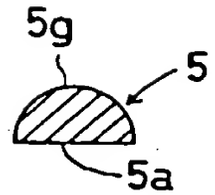


Fig. 3b

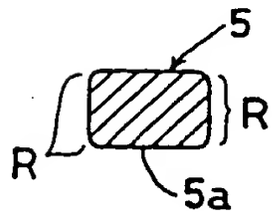


Fig. 4a

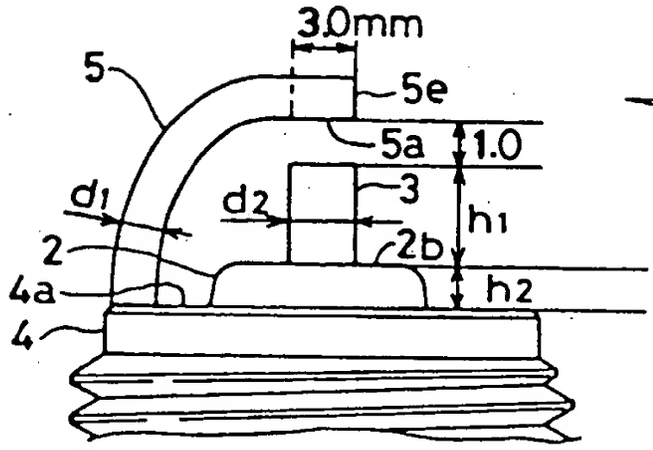


Fig. 4b

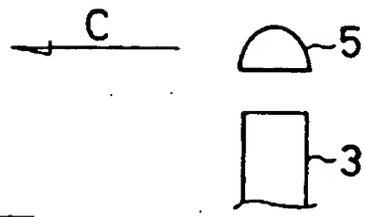


Fig. 5a

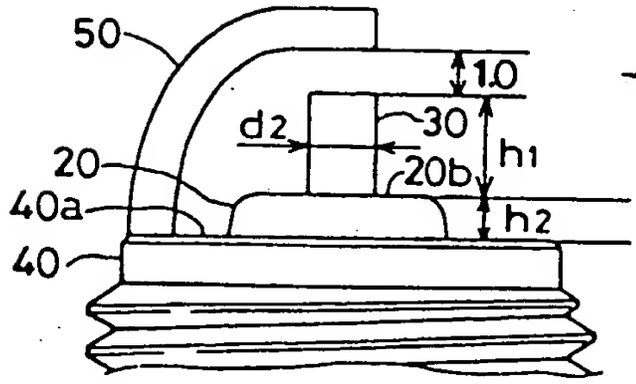


Fig. 5b

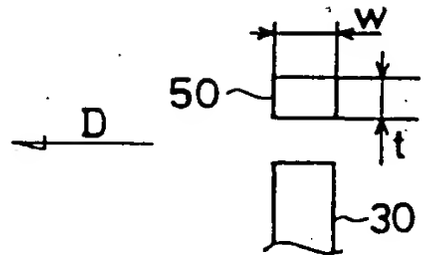
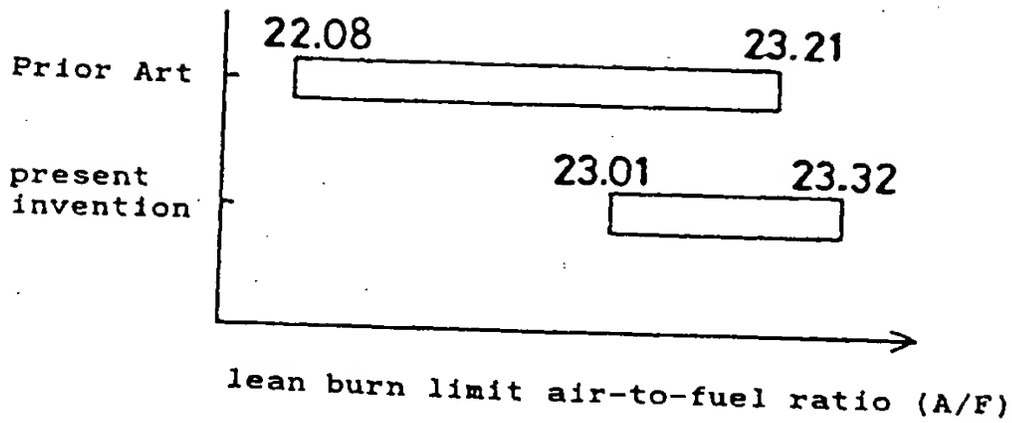


Fig. 6


22.08
23.21
Prior Art
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present
invention
lean burn limit air-to-fuel ratio (A/F)

Fig. 7a

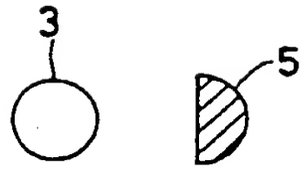


Fig. 7b

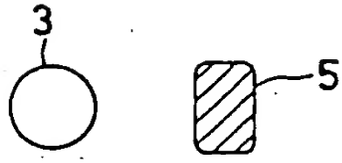


Fig. 7c

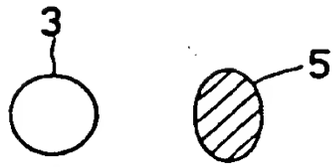


Fig. 8

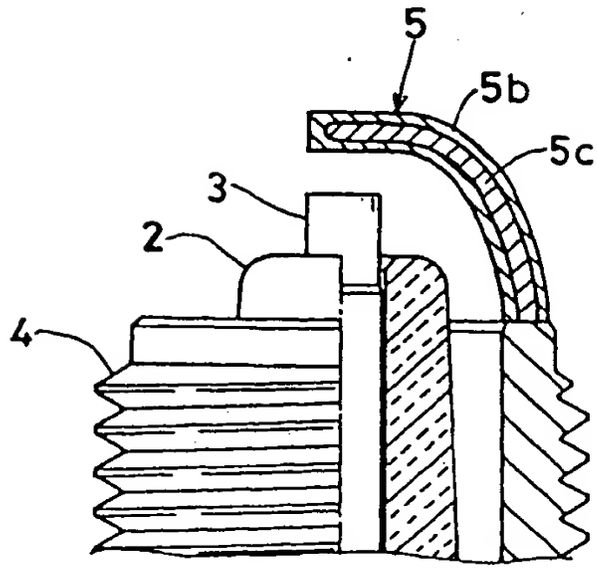


Fig. 9

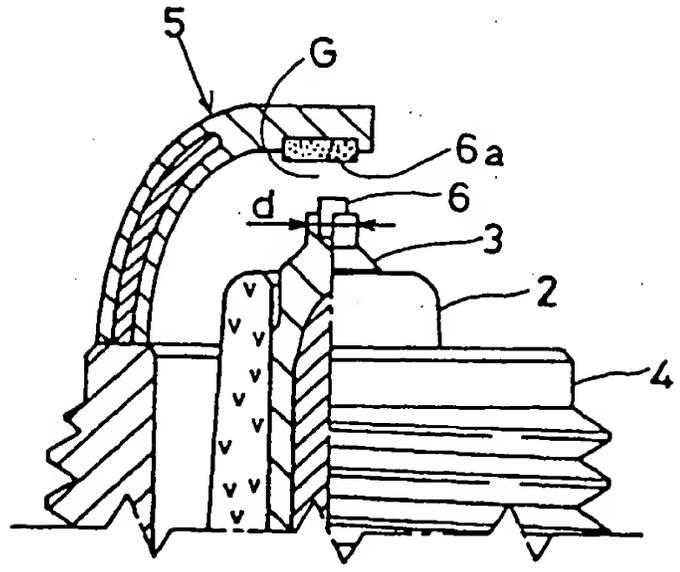


Fig. 10a

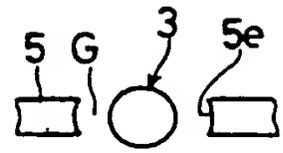


Fig. 10b

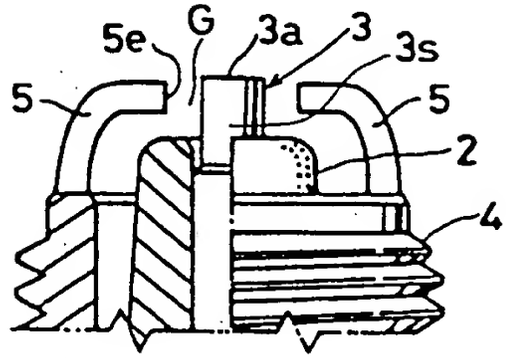


Fig. 11a

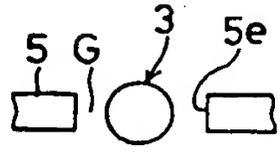


Fig. 11b

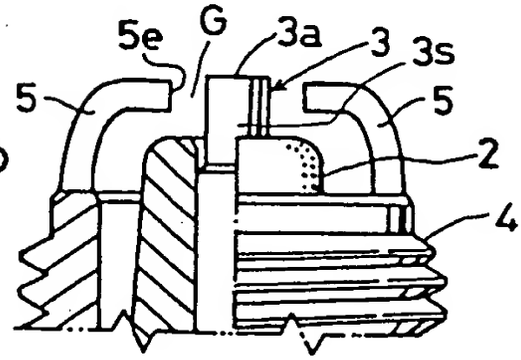


Fig. 12

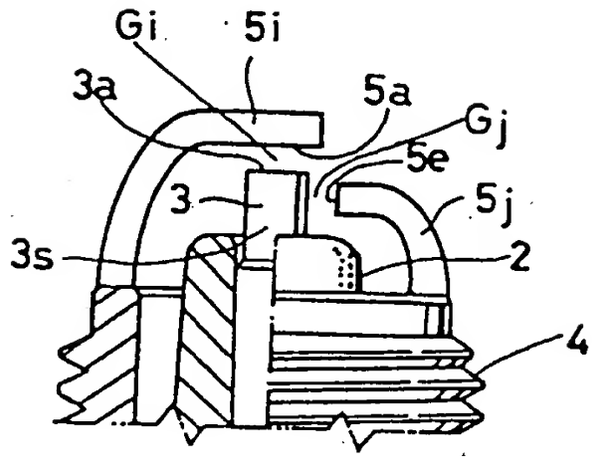
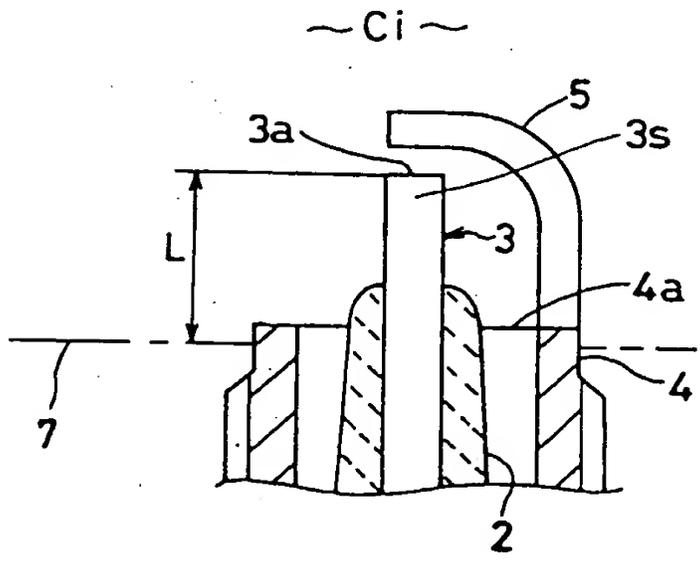


Fig. 13



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 0722

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-2 314 128 (COLDWELL) * page 2, left-hand column, line 8 - line 30; figure 1 *	1-4,8	H01T13/32
A	* page 2, right-hand column, line 12 - line 22; figure 9 *	10	
X	US-A-1 942 242 (FITZGERALD) * page 1, line 74 - line 105; figures 1-3 *	1,3,5	
A		10	
X	GB-A-2 027 797 (NGK SPARK PLUG)	1,6,8,9	
A	* page 3, line 110 - line 118; figure 17 *	7,10	
X	DE-U-88 11 215 (CHAMPION SPARK PLUG)	1,2,8, 11,12	
A	* page 10, line 6 - line 21; figures 1-3 *	9,10	
A	EP-A-0 518 707 (NGK SPARK PLUG) * column 3, line 9 * * claim 1 * * column 4, line 7 *	11-13	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01T

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 April 1996	Bijn, E

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